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NICKEL-CADMINUM STORAGE BATTERIES FOR CHINA'S
COMMUNICATIONS SATELLITES

by

Liu Linhui, Sun Yanbao

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NICKEL-CADMINUM STORAGE BATTERIES FOR CHINA'S COMMUNICATIONS SATELLITES

Liu Linhui Sun Yanbao

ABSTRACT

This paper discusses ceramic metal seal connection technology in single nickel-cadmium cells, factors influencing cell specific energies, and the influences of separator selection and cadmium electrodes on cell properties. On this foundation, it also expounds a step further on combined cell design, the production of shelf type structures, the use of carbon fiber material, and charging control technology.

SUBJECT TERMS Nickel-cadminum storage battery, Communication satellite, Design

I. FORWARD

As is generally known, nickel-cadmium storage batteries and solar cells are a match. In the several decades of the history of the applications of astronavigation electrical power supplies, they have played an important role. China--from the early 1960's--began research on nickel-cadmium storage batteries in space. Small power, cylindrical, fully sealed batteries were used successfully in 1971 and 1981 on "Shijian No.1" and "Shijian No.2". In the 1970's, probes began of square shaped, fully sealed nickel cadminum cells. In 1975, the mission was received to develop battery sets for the communications satellite "Dongfanghong No.2". In 1984, it was successfully launched. Useful battery life exceeded design values [1]. Soon afterwards, one after another, development of nickel-cadmiun storage batteries for communications satellite "Dongfanghong 2A" was completed, and, in conjunction with that, development was begun on the Fengyun series as well as the high power, long life "Dongfanghong No.3". Cell capacity developed from 1 Ah and 10 Ah up to 40 Ah and above. Cell specific energies developed from 23

Wh/kg to 45 Wh/kg. Powers developed from 4 W to over 1 kW. In the development of nickel-cadmium storage batteries, we absorbed advanced experience from abroad and, on the basis of domestic technology levels, carried out development and design of various types of battery parameters. From operating data on the numerous satellites already launched, it was clear that our designs were successful.

During China's over 30 years of nickel-cadmium storage battery development, gas leakage rate problems associated with fully sealed ceramic metal seal connection covers have been resolved. In order to raise specific energies, research has been carried out in such numerous areas as electrode base plates, active substance utilization rates, cover casing design, electrode column materials, and so on. Correlations were carried out on not only the material constituents of cell separators but on material working techniques as well. We also specified systematic methods associated with selection conditions for the configurations in front of cell seals as well as single mesh. Combined cell design developed from box types to shelf types. Composite materials developed from aluminum alloys to carbon fiber plates. Charging control selected for use temperature, T--V curves, as well as third electrode control. Precisely because the problems described above were gradually solved, only then did the performance of China's space nickel-cadmium storage batteries manage to satisfy the requirements posed by satellites as a whole, and, in conjunction with that, enter international levels of the 1980's.

II. NICKEL-CADMIUM SINGLE CELLS

Space applications of nickel-cadmium batteries are not the same as general nickel-cadmium storage batteries. There are other special requirements. The power source is the heart of the satellite. It determines the limits for satellite years of operation. Because of this, power supplies on satellites require high reliability and long life. Also, because their operation is under conditions of high vaccuum, it is required that battery gas leakage speeds reach $(10^{-6} \sim 10^{-8}) \times 133.3$Pal/s. In order to lower satellite launch mass, high cell specific energies are required. Their charging controls opt for the use of automatic controls and remote controls, etc. As a result, battery development must take the conditions described above as a basis.

1. Ceramic Metal Seal Connections

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As far as space applications of nickel-cadmium storage batteries are concerned, if there are slight gas or fluid leaks, it will cause battery fluids to dry up and solidify, making batteries lose efficiency. Because of this, research on completely sealed cell covers will be the guarantee of the reliability and long life of nickel-cadmium cells in space. There are two types of sealed structures--glass metal seals and ceramic metal seals. In the case of the former, because glass breaks easily and resistance to alkalinity is bad, use of the latter type of method in the practical use of nickel-cadmium storage batteries in space is, therefore, more common. Early on, we opted for the use of sintered metal powder methods--for example, molybdenum-manganese methods. However, this type of material, in and of itself, has bad resistance to alkalinity. In use, it is easy to create corrosion. If solder is also not selected appropriately, cell use will not reach one year. There are then 30% of covers which short circuit because of seal material corrosion. Later, on the basis of a changeover to ceramic metal industrial processes and improvement of solder, it was only then that short circuits produced because of materials corrosion were avoided.

As far as the quality of seal properties are concerned, there are also close relationships to seal structures and industrial techniques. In order to make the two types of ceramic and metallic materials--with completely different physical and chemical properties--seal tightly, and, at the same time, be able to maintain seal properties for long periods, the removal of seal stresses is extremely important. Moreover, clamp seal structures are better than single surface flat seals. The reason is that seal connection stresses associated with this type of structure are relatively small. Strength is high. Thermal shock properties are also relatively good. In order to eliminate seal connection stresses, it is also possible--between seal members--to use replaceable transitional parts in low temperature phases when ceramic expansion coefficients are relatively close. In conjunction with this, the working conditions are strictly controled, and the stability of ceramic replacable cover mechanical properties is guaranteed.

2. Cell Specific Energies

Specific energies of nickel-cadmium storage batteries associated with communications satellites are very important technological indicators. The life of nickel-cadmium storage batteries and their capacities are determined by hydrogen and oxygen subcompounds of nickel as well as hydrogen and oxygen compounds of cadmium from positive and negative electrode active substances as well as electrolyzed materials. Therefore, if one wishes to raise cell specific energies, one should increase the percentage of active substance components. In conjunction with this, their rates of utilization are raised and the mass of non active battery components goes down [2,3].

Research over the last many years clearly shows that improvements in electrode framework thicknesses and porousness are capable of making their mass drop 20 ~ 30%. Electrode base plates, through the selection of such conditions as the type of hole creating agents, the particle distribution of hole creating agents, sintering temperature, sintering time, and so on, are capable of making base plate porousness increase from 74% to over 80%. Increases in porousness make increases in the amounts of electrode plate active substances loaded into them go up approximately 20%, causing cell specific energies to show a large increase. As far as electrode thicknesses are concerned, abroad, there have been many options for the use of thin form electrode plates. However, we--on the foundation of computer optimized design--have suitably increased thicknesses as shown in Table 1. With regard to nickel-cadmium storage batteries with 3 ~ 5 year lives, this type of design has been proved feasible in practical application. Lowering the active substance content of positive and

Table 1 Thicknesses of Battery Electrodes in Different Models

1 型号 / 6 项目	2 国际通信卫星Ⅳ	3 国际通信卫星Ⅴ	GE	4 东方红2号	5 东方红2号甲
7 正极厚度 (mm)	0.69	0.69	0.69	0.76	0.88
8 负极厚度 (mm)	0.80	0.74	0.79	0.94	1.02

Key: (1) Model (2) International Communications Satellite IV (3) International Communications Satellite V (4) Dongfanghong No.2 (5) Dongfanghong No.2A (6) Item (7) Positive Electrode Thickness (8) Negative Electrode Thickness

negative electrodes is also capable of increasing cell specific energies. Moreover, it is a relatively effective measure. However, with regard to satellites under different utilization conditions, cadmium electrode properties necessarily are dealt with case by case. Otherwise, it will influence cell reliability and life. With regard to the mass of other inactive parts in cells, they are principally determined by such things as operating conditions, material properties associated with various nations, as well as levels of industrial working techniques, and so on. In Table 3, comparisions are set out for the masses of various cell set components associated with several models. From the Table, one can see that, with regard to high specific energy cells, the masses of nonactive components gradually drop. The single nickel-cadmium cell we developed for "Dongfanghong No.3" reached 29.6g/Ah, exceeding the index for communications satellite V.

Table 2 Distribution of Various Component Masses in Different Models of Cell

1 类别 / 6 项目	2 通信卫星IV		3 通信卫星V		4 东方红2号		5 东方红3号	
	(g)	%	(g)	%	(g)	%	(g)	%
7 极板组	442.6	68.0	767.4	74.8	361	62.5	900	67.7
8 壳盖	139.6	21.5	120.7	11.8	127	22.0	234	17.6
9 电解质	59.3	9.1	114.5	11.2	70.0	12.1	160	12.0
10 隔膜	9.3	1.4	17.6	1.7	17.0	2.9	30	2.3
11 垫			5.2		3.0		6	
12 电池	650.8	100	1 025.4	100	578	100	1 330	100
13 安时重 (g/Ah)	43.4		30.2		44.5		29.6	

Key: (1) Type (2) Communications Satellite IV
(3) Communications Satellite V (4) Dongfanghong No.2
(5) Dongfanghong No.2 (6) Item (7) Electrode Base Components
(8) Casings (9) Electrolyte (10) Separators (11) Pads
(12) Cells (13) Amp-Hour Weights

3. Separator Research

Separators in cells--besides isolating positive and negative electrodes--also need to guarantee ion electrical conductance properties in solutions. Acting as sealed nickel-cadmiun storage battery separators, one must also have good gas permeability properties. Researchers inside and outside China, at the same time as developing space nickel-cadmium storage batteries, have all begun to develop cell separators and to study such things as separator materials, separator manufacturing industrial techniques, and the effects of different separators on cell properties [4,5]. The distinctions between the properties of different separators are very large (Table 3 only sets out property comparisions for a few types of separators). Moreover, as far as cell property influences are concerned, there are clear differences. This is not only because their property stability influences cell life, but also, is relatively strongly related to cell initial properties. Table 4 sets out the influences of several types of membrane on cell properties.

Table 3 Property Comparisons for Several Types of Separators

1 类别 / 7 项目	氯乙烯—丙烯 2 腈毡	过氯乙烯 3 毡	维尼龙 4 纸	尼龙 5 纸	尼龙 6 毡
8 厚度mm	0.2±0.02	0.1±0.02	0.12±0.02	0.24±0.02	0.1±0.01
9 密度g/m²	30～40	20～30	30～40	50～70	20～30
10 吸碱率%	≥400	≥400	≥110	≥200	≥300
11 抗拉强度kg/cm²	230	30	80	30	160

Key: (1) Type (2) Vinyl Chloride--Acrylic Fiber Felt (3) Vinyl Perchloride Felt (4) Vinylon Paper (5) Nylon Paper (6) Nylon Felt (7) Item (8) Thickness (9) Density (10) Alkaline Absorption Rate (11) Tensile Strength

Table 4 Influences of Various Types of Separators on Cell Properties

7 项 目 \ 1 类 别	氯乙烯—丙烯 2 腈毡	过氯乙烯 3 毡	维尼龙 4 纸	尼 龙 5 纸	尼 龙 6 毡
8 活性物质利用率（%）	79.5	80.5	78.5	81.0	80.7
9 电池30天自放电（%）	48.0 11	37.3 11	28.4	29.1	30.4
10 电池充电终压（V）	>1.50电池鼓	>1.50电池鼓	>1.50	1.47	1.49

Key: (1) Type (2) Vinyl Chloride--Acrylic Fiber Felt (3) Vinyl Perchloride Felt (4) Vinylon Paper (5) Nylon Paper (6) Nylon Felt (7) Item (8) Active Substance Utilization Rate (9) Cell 30 Day Self-Discharge (10) Cell Charging Terminal Voltage (11) Cell Drum

Outside China, options for the use of nonwoven nylon separators in space electrical power sources are relatively numerous. In conjunction with this, they go through control of cell utilization temperatures in order to limit the speed of nylon breakdown in alkali [6]. China's space electrical power source separator membranes select for use nylon and vinylon primarily. Moreover, there are multiple layers of composite separator membrane--considering not only separator membrane general properties and permeability but also considering the blocking functions on cadmium ion migration. As far as our opting for the use of composite separator membranes is concerned, initial cell capacities were increased 5 ~ 10% as compared to the use of single type nonwoven nylon membranes. Cell 5 year cycle strength changes are relatively small. After 10 years of storage, separator membrane strengths were almost unchanged. This was precisely because separator membrane selection was rational, guaranteeing the reliability in long term operation of space cells.

4. Cadmium Electrode Effects on Cell Performance

In sealed cells, cadmium electrode capacities are excessive. As far as the magnitude of the excess is concerned, the status of the excess portion and the basic properties of cadmium electrodes themselves have very large influences on cell characterisitics. Because of different technical cell requirements, the specific values in question are capable of varying between 1:1.3 ~ 1:2.2. Specific value selections are relatively small. This is advantageous for increasing specific energies. Due to the fact that, during utilization processes of nickel-cadmium cells, it is very easy to inactivate electrode surfaces, structures will produce changes, and crystal particle collections will grow in conjunction. In particular, under utilization conditions with high temperatures and shallow charging, it is easy to influence cell performance. Because of this, with regard to strict requirements for cell performance or long life in nickel-cadmium cells, the ratio of the capacities of positive and negative electrodes cannot be selected too small. In normal situations, selections of 1:1.5 ~ 1:1.8 are relatively appropriate.

Status control of the properties of cadmium electrodes themselves as well as cadmium electrode excess capacities before sealing will influence nickel-cadmium cell charging voltages, pressures within cells, as well as the magnitude of cell capacities [7]. In our research on cadmium electrodes, first of all, studies were done of cadmium electrode oxygen absorption mechanisms, supplying us with a basis for cell design. Next, studies were done on the influences of cadmium electrode additives on cadmium electrode performance. Third, studies were done on the relationships between status control of cadmium excess capacities before cell sealing and cell performance. Fig.1 is charging and discharging curves associated with different configuration control of cells. Fig.2 is life cycle test results associated with different configuration control of cells. From the Fig.'s it is possible to know that, even if

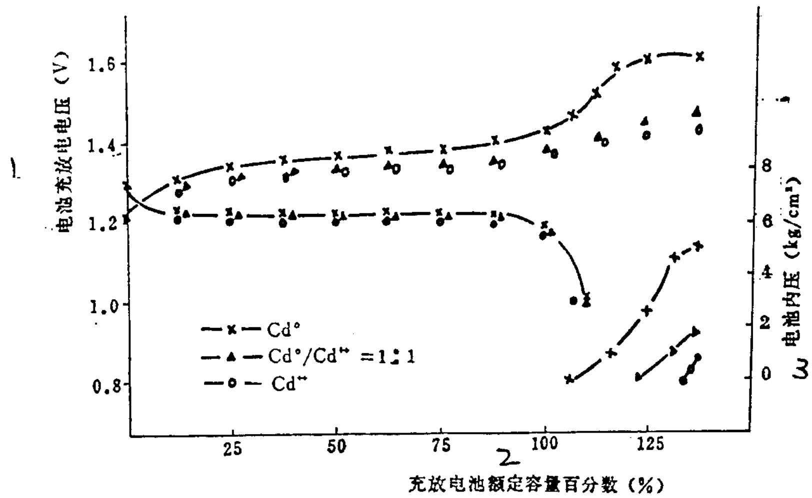

Fig.1 Influences of Different Cadmium Excess Capacity Statuses on Cell Performance

Key: (1) Cell Charging and Discharging Voltages (2) Charging and Discharging Cell Rated Capacity Percentage (3) Cell Interior Pressure

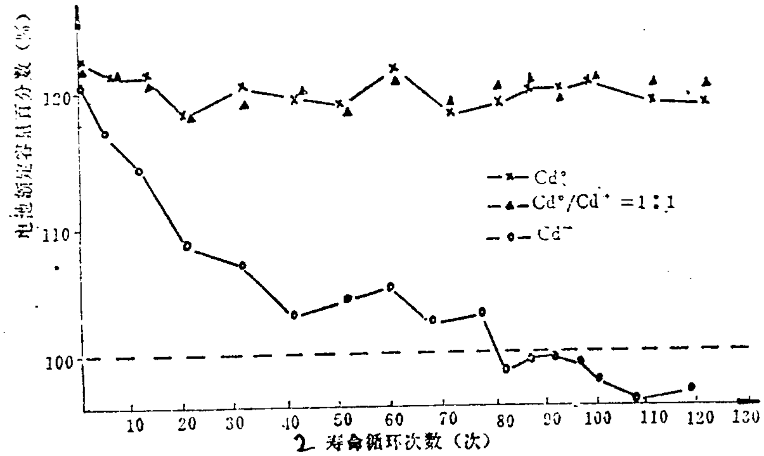

Fig.2 Influences of Different Configurations of Excess Cadmium Capacities in Cells on Cell Life

Key: (1) Cell Rated Capacity Percentage (2) Number of Life Cycle Iterations /38

cadmium electrode properties themselves are very good, due to the fact that configuration controls on cadmium electrodes before sealing are inappropriate, however, it makes cell properties relatively bad. In development processes for the practical use of communications satellites, we resolved the methods for cadmium electrode status control, thus causing cell life to increase from 2 year to over 3 years. In summary, in sealed nickel-cadmium storage cells, as long as designs are appropriate, cells should be positively limited, positive electrodes determing cell capacity magnitudes, and negative electrodes determining cell property stability conditions. Because of this, space nickel-cadmium storage batteries have very strict requirements for negative electrodes.

III. COMPOSITE CELLS

Space nickel-cadmium batteries require light weight, tests for the ability to accept mechanical conditions, and special thermal design requirements fitting cells.

1. Composite Structures

From the 1960's to the early 1970's, we developed space nickel-cadmium batteries opting for the use of box type structures. Due to cell charging internal pressures going up, in order to prevent casing deformations, composite outside shells must have a certain thickness. Because of this, composite components account for 23% of total battery weight. In the design of "Dongfanghong No.2" batteries, option is made for the use of shelf type structures and titanium material pull rods, making composite component weight drop to 18% of battery weight. In recent years, composite materials have rapidly developed. Carbon fibers with light weight and good strength have achieved broad applications. In "Dongfanghong No.3", option is made for the use of carbon fiber plates to replace aluminum alloy plates. Drops in material specific gravity alone are capable of making mass lighten 34%. The use of new materials makes "Dongfanghong No.3" composite components account for 13% of battery mass, reaching international levels for the early 1980's.

2. Composite Thermal Design

Nickel-cadmium cell thermodynamic reaction equations are

$$2NiOOH+2H_2O+Cd \underset{\text{充电 }2}{\overset{1\text{ 放电}}{\rightleftharpoons}} 2Ni(OH)_2+Cd(OH)_2-139kJ/mol$$

Key to above: (1) Discharging (2) Charging

Cell charging is an endothermic reaction. Discharging is an exothermic reaction.

The quality of nickel-cadmium cell performance, length of life, and temperature are closely related. Moreover, a good number of researchers have proved that optimum cell operating temperatures are 0 ~ 15°C [8].

We are capable, on the basis of the formulae described below, of calculating the amount of heat put out Q when cells discharge, the amount of cell external work w, as well as solving for molar active substance enthalpy change values ΔH [9].

$$Q = c \cdot m \cdot \Delta t$$

$$w = 0.86 \int_0^\tau V \mathrm{d}\tau \approx 0.86 \cdot I \cdot V \cdot \tau$$

$$\Delta H = \frac{Q - w}{n}$$

In the formulae c----measured cell specific heat

m----battery mass

Δt----temperature rise during discharge processes

V----average discharge voltage

I----discharge current

τ----discharge time.

However, in actual use, due to different levels of industrial technique associated with preparing cells, there are, therefore, differences in materials used. Various set component masses are different, and, so, actual amounts of heat put out in association with different cells have certain differences in values. Under general conditions, the larger ohm resistances associated with cells are, the larger amounts of cell heat put out also are. Although cell charging is an endothermic process, due to the influence of heat put out by internal resistances, there are times when charging processes are difficult to see as changes associated with drops in cell temperature. If charging currents are relatively small, then, it is possible to observe the whole process of charging process cell temperature drops and rises. Fig.3 is temperature change patterns associated with "Dongfanghong No.2" single cells developed by us using C/10 charging times. From the Fig., it is possible to know that when cell amounts of charging put in are 80% of actual capacities, cell temperatures do not change. At the stage of 80% amounts of charge put in, cell temperatures drop 1.5°C. When amounts of electric charge put in are 110%, cell temperatures rise 7°C. When amounts of electric charge put in are 120%, temperatures go up over 10°C. Making explanations from the patterns of change described above, as long as charging currents and amounts of overcharging are selected appropriately, during normal storage battery charging, temperature changes are relatively small.

Cell discharge is an exothermic process. It can be divided into two parts--reversable heating and nonreversable heating. These amounts of heat will all produce cell temperature rises. Taking "Dongfanghong No.2" single units as an example, cell weight is 580g. Using 6.5A discharge average rates of heat produced as being 1.3~1.4 W, cell specific heat is 0.921J/g•°C [10]. In adiabatic processes, cell discharges of 1.2 hours are associated with cell temperature rises of 11°C. Because of this, how to take amounts of heat during cell discharge and dissipate as fast as possible and how to maintain temperature uniformity between single cells during battery operation will be important contents associated with composite thermal design. Besides satellites as a whole adopting necessary measures during temperature control design, nickel-cadmium cells--during single unit design and composite design--will all be earnestly considered. "Dongfanghong No.2" composite design opts for the use of subcomponent shelf type structures. In modules, specialized heat channels were designed. Side cells also have insulation plates designed into them. Single unit outer casings opt for the use of such measures as polishing treatments. When batteries are in operation, temperature changes are generally smaller than 15°C. Among components, single unit temperature differences are smaller than 3°C. With regard to high power communications satellite nickel-cadmium storage batteries, thermal designs will be much more complicated. During discharge, amounts of heat given off will increase to double. In order to reduce cell temperature rises, radiation speeds during discharge are quite important. Starting out from rationality in power source system design, during charging processes, battery temperature changes are not great. However, how radiation during discharge matches up with charging process thermal design must be more fully and comprehensively considered. Comparing powers of communications satellites V and IV, they increase from 480 W to 1270 W. The thermal designs--besides selecting good positions for power dissipation, selecting optimized use surface coatings, meticulous design of heat transfer paths, and opting for the use of T shaped heat conducting plates--also added heaters, guaranteeing that storage batteries, in low temperature environments, will not be below lower limit temperatures.

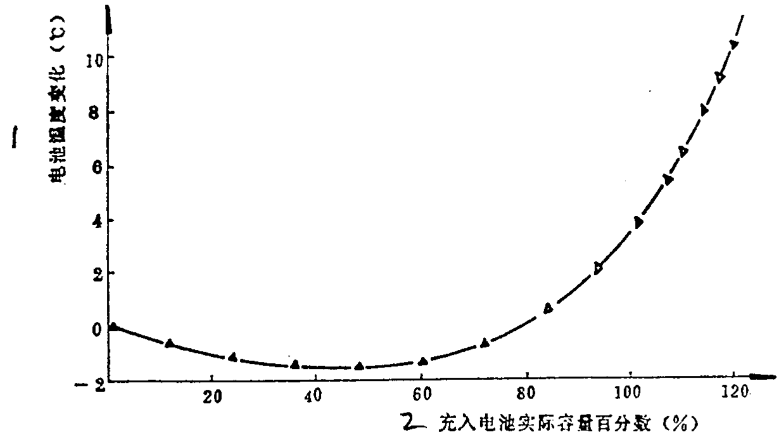

Fig.3 Relationships Between Amounts of Electric Charge Put in and Cell Temperature Changes During C/10 Cell Charging Rates

Key: (1) Cell Temperature Change (2) Charging Cell Actual Capacity Percentage

IV. CHARGING CONTROL

Reliable charging control is the key to guaranteeing long nickel-cadmium cell life. So called charging control is storage cells taking charging currents and charging to "full electric charge", and, at that time, cells giving out a "signal value". On the basis of these signal values, battery charging currents turn into "safeguard" current processes. At the present time, there are already a series of charging control methods which have become mature--for example, electric quantity control, voltage control, pressure control, temperature control, recharging rate controls, and so on. Electric quantity control is batteries generally opting for the use of constant current charging using special cadmium-cadmiun coulomb meters or electron voltameters to record the amount of electricity being charged into batteries. When an indicated amount of electricity is reached, safeguards are carried out for the battery. Voltage controls are methods--

when utilizing storage batteries in normal charging--of battery voltage characteristics following along with the execution of charging and gradually going up and taking a certain voltage value to act as charging termination "signal" to carry out safeguarding of the battery. Pressure control is utilizing storage cell periods after charging as well as process phases and the principle of cell interior oxygen pressures gradually going up to make it possible to utilize sensors of differences in pressure (mechanical or electrochemical) in order to indicate oxygen pressure values for charging termination, thereby carrying out charging control. Temperature control is a method utilizing the characteristics of periods after charging--after cell interiors produce cadmium-oxygen cycles--of storage cell temperatures abruptly rising in order to control charging. Recharging rate control, in actuality, is a type of charging control method associated with the mutual combining of multiple levels of constant current charging and other charging controls.

The various charging control methods described above are mostly single value function changes associated with storage cell charging processes and will accurately determine "full electric charges" in reacting storage cells. Functions associated with a certain single value are all not easy to accurately realize. With regard to what has already been described, if one wants to guarantee battery reliability and long life, strictly controling storage battery temperature is the key. Taking voltage control for example, storage cell charging voltages--besides being related to the amount of charging--are also related to such factors as numbers of cycle iterations, cell temperatures, and so on. From Fig.3, it is possible to know that temperatures in periods after storage cell charging go up. Because storage cell temperature coefficients are negative values, if charging termimation voltages are selected inappropriately, it will create severe storage cell overcharging and what are called "thermal control loss" phenomena. Therefore, voltage controls actually used in satellites are all multiple BVL curves associated with temperature compensation as shown in Fig.4. In order to increase cell reliability, charging controls are all comprehensive utiliztion of multiple types of methods--using one type of control method as primary and several types of control method to be supplementary charging control methods. Almost all actual satellite uses outside of China are like this--for example, ATS-6 opts for the use of voltage temperature compensation and, in conjunction with this, selects for use two types of C/10 and C/20 charging rates as well as 35°C upper temperature limit safeguards. Remote control commands are also used as back up. NATO-III, too, opts for the use of fixed voltage sequence controls, and, in conjunction, selects for use upper limit temperature safeguards of 29°C. It still uses ground commands as back up measures.

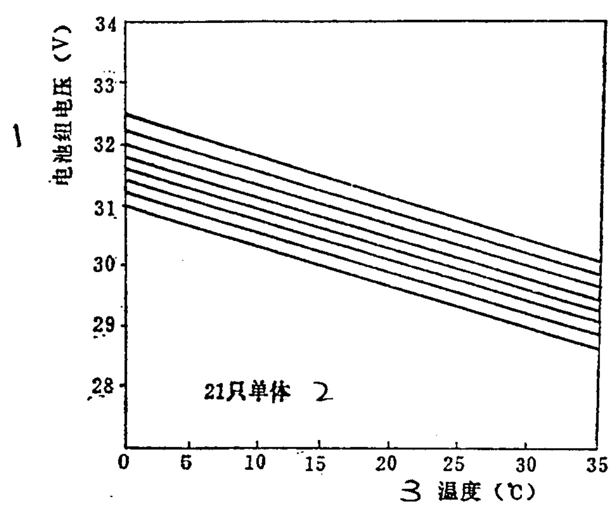

Fig.4 Multiple BVL Curve Groups Associated with Temperature Compensation

Key: (1) Battery Voltage (2) Single Units (3) Temperature

As far as communication satellites which China has developed are concerned, in order to guarantee the reliability of charging control methods, they also select for use charging control plans which mutually combine different types of charging control methods. Outside China, due to the fact that problems in the use of pressure control methods were relatively numerous--besides there being some reports on early stages of research--it is only used in OAO-II satellites. However, China, on the foundation of fuel cell electrode research, is again tending toward the characteristics of nickel-cadmium cells. Going through 5 years of development, a series of application problems were resolved, making electrochemical pressure sensor--third electrodes act as main control measures for application on the first "Dongfanghong No.2" communications satellite. Life exceeded 4 years. "Signals" were normal. After this, there were applications again in "Dongfanghong 2A". Utilization was also continued in "Fengyun No.2". Besides pressure control methods, we also studied cadmium-cadmium coulomb meter methods, temperature compensation voltage control methods, temperature control methods, and so on. The latter two types of methods have already been applied in satellites.

V. CONCLUDING REMARKS

With regard to nickel-cadmium storage cells, their acting as energy storage electrical power sources associated with solar cell--energy storage device systems has played an important role in space applications for the last 30 years. In the case of development and production of space nickel-cadmium storage cells over the last ten to twenty years, they have been applied in various models of satellites and have made contributions to the Chinese spaceflight industry. In recent years, the development of hydrogen-nickel cells--due to their long life, simplicity of control, high specific energies, resistance to overcharging, and other such advantages--has been applied on satellites for ten years abroad. In conjunction with this, it has already been applied on such satellites as communications satellite V. Hereafter, the range of applications will expand. However, their inadequcies--such as small specific energies by volume, bad thermal characteristics, and so on--will not be easy to alter.

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REFERENCES

1 Lin Linghui. The Development and Flight Performance of CAINA'S Satellites Power Systems, 37th Congress of the IAF 1986

2 Willard R Scott, et al. Sealed-Cell Nickel—Cadmium Battery Applications Manual. NASA N80-16095, 1979

3 Ritterman F, Bogner R S. Development of Long Live Lightweight Ni-Cd Cells and Battevies, 13th IECEC, 1978, 62~66

4 Milden M J. Separator Qualification for Aerospace Ni-Cd Cells, 19th IECEC. 1984, 108~110

5 Francis R W. Aerospace Ni—Cd Cell Separator Qualification Program 21th IECEC, 1986, 1484~1489

6 27th proc.p.s.s. Studies on the Stability of Nylon Separator material, Hong Sup Lim, 1978, P83~85

7 Eimmerman A H. Effects of Cadmium Electrode Properties of2Ni—Cd Cell Performance, 21th IECEC, 1986, 1501~1505

8 Evaluation Program for Secondard Spacecraft Cells; Cycle Life Test Annual Repores

N65—26408	N71—17470	N76—26687
N66—29760	N72—24038	N78—31540
N68—34752	N73—26046	N81—17529
N69—36703	N74—26502	N81—27618
N70—23598	N75—19822	

9 胡金刚, 黄金垒.卫星用镉镍电池热物理性参数的测定.电源技术.第4期, 1984, 5~12

10 Armantrout J. Goddard Space Flight Center Battery Workeshop. 1979, 287~297

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C513 ARRADCOM	1
C535 AVRADCOM/TSARCOM	1
C539 TRASANA	1
Q592 FSTC	4
Q619 MSIC REDSTONE	1
Q008 NTIC	1
Q043 AFMIC-IS	1
E404 AEDC/DOF	1
E408 AFWL	1
E410 AFDTC/IN	1
E429 SD/IND	1
P005 DOE/ISA/DDI	1
P050 CIA/OCR/ADD/SD	2
1051 AFIT/LDE	1
P090 NSA/CDB	1

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